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FOOD SELECTION AND FEEDING RELATIONSHIPS OF YELLOW PERCH 'PERCA FLAVESCENS' (MITCHELL), WHITE BASS 'MORONE CHRYSOPS' (RAFINESQUE), FRESHWATER DRUM 'APLODINOTUS GRUNNIENS' (RAFINESQUE), AND GOLDFISH 'CARASSIUS AURATUS' (LINNEAUS) IN WESTERN LAKE ERIE

David E. Kenaga, et al

Michigan State University

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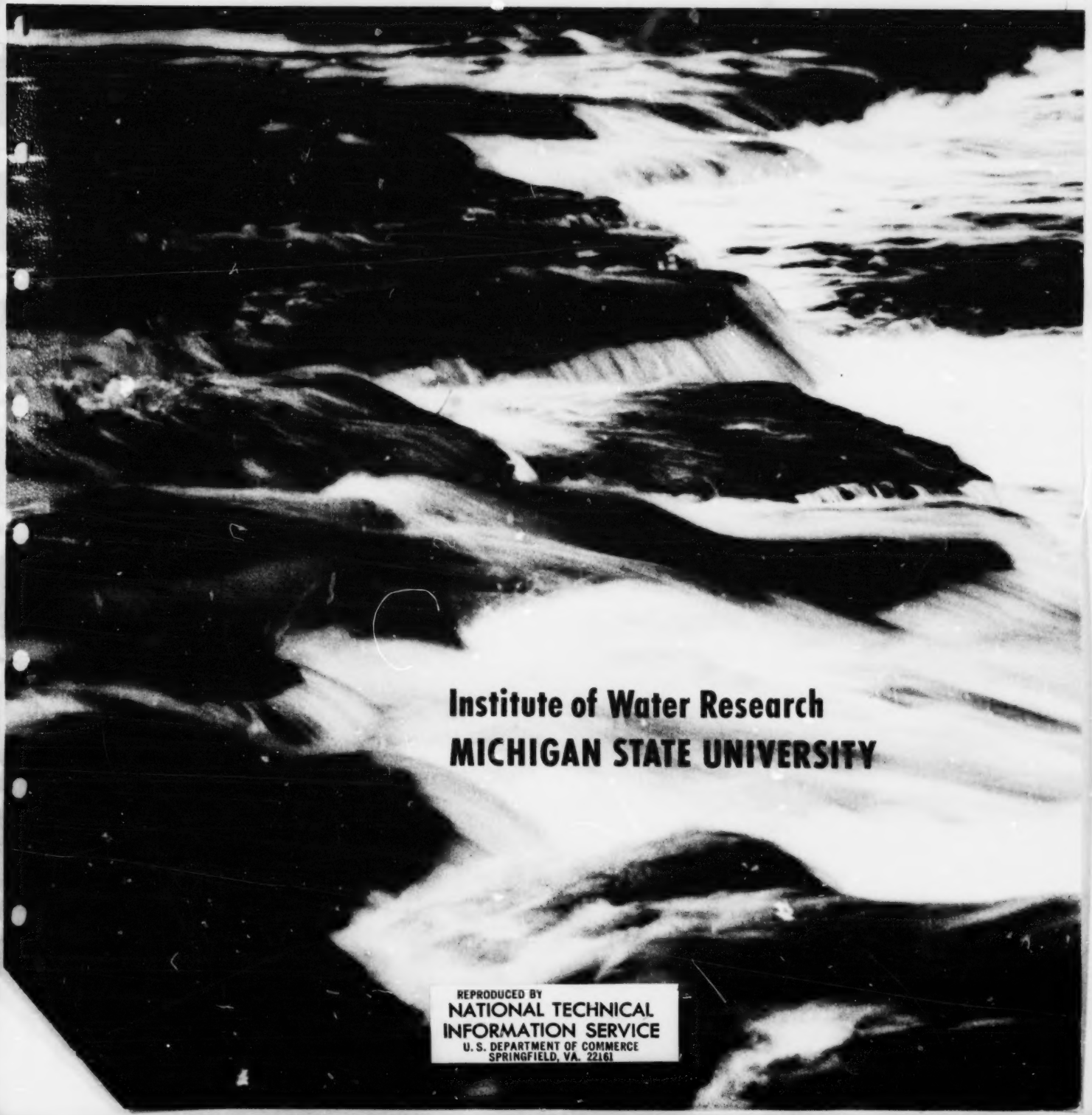
by D. E. Kenaga and R. A. Cole

October 1975



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Michigan State University
East Lansing, Michigan

Technical Report No. 32.5
Thermal Discharge Series

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ABSTRACT

FOOD SELECTION AND FEEDING RELATIONSHIPS OF YELLOW PERCH PERCA FLAVESCENS (MITCHILL), WHITE BASS MORONE CHRYSOPS (RAFINESQUE), FRESHWATER DRUM APLODINOTUS GRUNNIENS (RAFINESQUE) AND GOLDFISH CARASSIUS AURATUS (LINNEAUS) IN WESTERN LAKE ERIE

This study was undertaken as part of an investigation of the impact of once through cooling at a large power plant in Western Lake Erie and is an attempt to assess the relationship among fish based on foods consumed. Potential food organisms and stomach contents of yellow perch, white bass, freshwater drum and goldfish were sampled and compared over a two year period. On the basis of differences in food size alone, young of the year fish did not appear to be in competition but as they became larger, all but goldfish consumed the same mean size foods. Within a fish species, mean prey size varied little in fish older than age class zero. Goldfish differed markedly by lacking the prey size selectivity demonstrated by the other fish species. Perch, drum and white bass preferred large organisms, specifically *Leptodora kindtii* and *Chironomus* sp. while goldfish consumed smaller species, particularly cyclopoid copepods. Some ramifications of food size and prey selectivity in relation to trophic dynamics, feeding efficiency, composition and distribution of fish species, and the use of cooling water by large power plants and their possible impact upon prey size were discussed.

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INTRODUCTION

The network of trophic linkages in aquatic communities is a fundamental mechanism for population interaction. However, the quantification of trophic relations is just beginning to produce a manageable theory of trophic regulation based on a combination of results from exploratory field studies by workers like Ivlev (1961), Brooks and Dodson (1965) Hrbacek *et al.* (1961), Galbraith (1966), and the environmentally simplified but highly controlled experiments of workers like Hall *et al.* (1970), and Werner (1974). The purpose of this paper is to present data that will assist in the understanding of food selection processes by warm-water fishes in a highly altered aquatic environment near an operational power plant on the west shore of Lake Erie. My goal was to determine which organisms were consumed by fish and the importance of prey size in food selection. Through this process I attempted to reveal potential intraspecific or interspecific competition among fish based on food sizes alone.

The mushrooming concern over man's impact on natural ecosystems has stimulated research on many ecological aspects including trophic relationships. Much of this research is designed to quantify the direction and rates of material and energy flow through natural communities. This quantification of ecological processes will allow a more accurate comparative evaluation of man-made and natural resource values resulting in more effective resource management.

One outstanding example of potentially conflicting use of aquatic resources is the co-existant demand for fisheries and power plant cooling water. There is a growing realization that the effects of power plant operation on entrained aquatic organisms may be related to the size of animals which pass through the cooling system because larger animals are more vulnerable to mechanical damage (McNaught, 1972). Marcy (1973) for example has shown that nearly all of the relatively large ichthyoplankton passing through a power plant were killed. Other studies indicate that organisms of smaller size (most zooplankton) suffer less damage during passage through power plants than the larger ichthyoplankters (Davies and Jensen, 1975; Isaacberry and Adams, 1974). Even though there is now no clear relationship distinctly demonstrated between size of entrained organisms and the probability of mortality, the limited existing information points to this possibility.

This is especially important because prey size is one of several mechanisms by which predators choose their food (Hrbacek *et al.*, 1958; Carr and Hiltunen, 1965; Galbraith, 1967; Brooks and Dodson, 1965; Hutchinson, 1971; Grygierek, Hillbricht-Ilkowska, 1966; Hall *et al.*, 1970; and others). Thus, any modification of prey species composition by power plant or other similar activity may have subtle effects on fish species composition and abundance. With these concerns in mind, this study was undertaken to assess the food habits and relationships between food availability and feeding of several important fish species near a large power plant with the anticipation that future studies will define more clearly the relationships within power plant cooling systems.

METHODS

The Study Site

This study was conducted along the western shore of Lake Erie near the Monroe power plant at the mouth of the Raisin River (Figure 1). This plant has been the focal point for a comprehensive ecological sampling program through which data for this paper were gathered. Data were taken for this study in 1971 and 1972, during which time cooling water was drawn from both the lake and river at variable rates (most frequently at about 50 m^3/sec.) and discharged through a 2.5 km canal into the lake (Figure 1). At that time, the power plant was partially completed and operational shut-downs were common. Cooling processes elevated water temperatures up to 10 C as measured in the upper discharge canal.

Western Lake Erie is shallow and highly turbid because of continual, wind-generated resuspension of bottom sediments and siltation from the Maumee River and other lesser tributaries. Temperatures and oxygen concentrations are generally uniform because of continuous mixing. Lake water transparency, determined by Secchi disc measurements, rarely exceeds 2 m and is most commonly less than 0.5 m. The bottom of the western basin is physically uniform and gently slopes to a maximum depth of 5 m in the study area. Geographical discontinuities along shore, like the Raisin River and the discharge canal, are the outstanding deviations from an otherwise uniform environment.

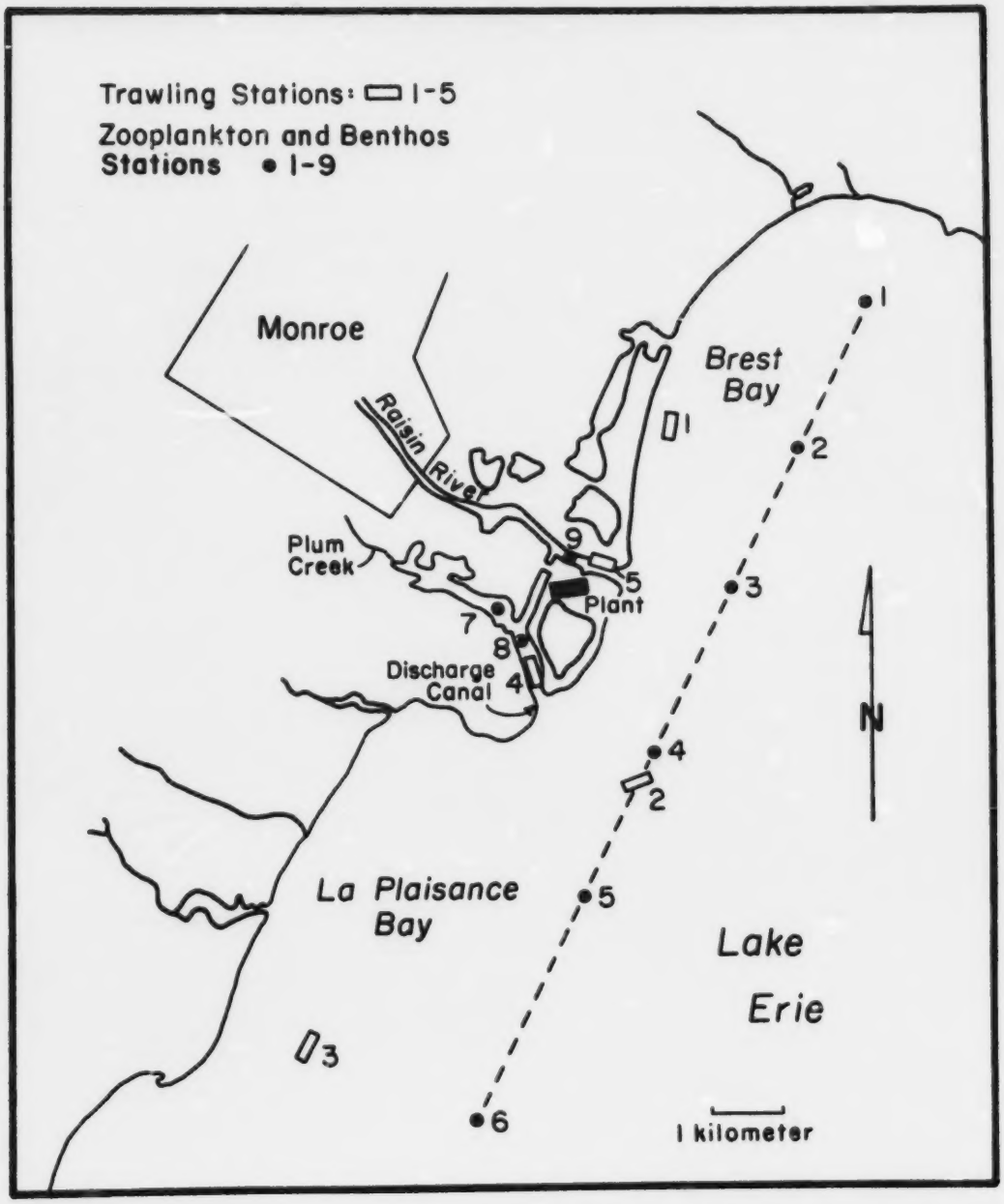

Figure 1. Map of the Study Area

Perhaps because of physical uniformity in this system, zooplankton populations are also relatively uniformly distributed throughout the study area. Nalepa (1972) has shown that the "relative densities and biomass (expressed as %) of the major zooplankton taxa varied little within the lake" (Figures 2 and 3). Greatest variance from mean composition throughout the study area occurred in the river and inshore discharge area. Although on a given date, variations among stations within the study area are up to 100% or more, they tend not to be consistant in the lake from one sampling date to the next; therefore, variations are dampened over an annual cycle. To check Nalepa's findings, additional triplicate zooplankton samples from the fish and zooplankton collecting sites were collected and compared for two separate dates. A multivariate ANOVA likelihood ratio test (Kramer, 1972; Harris, 1975) was run and no significant differences were indicated between collection stations. Nalepa (1972) also found that vertical planktonic variation was less than the horizontal variation observed over the study area, usually with less than a 20 to 30% difference.

The homogeneous character of western Lake Erie was remarked upon by Verduin (1964) and the IJC (1969), and if the food in the study area is homogeneously distributed, then the potential for differential prey concentrations influencing food composition in fish stomachs is negligible. Therefore, selection indices which are calculated from samples obtained over a seasonal time span and from widely divergent regions of the study area should minimize the probability of identifying a size selection process if it occurs because of the array of temporal and spatial variability incorporated

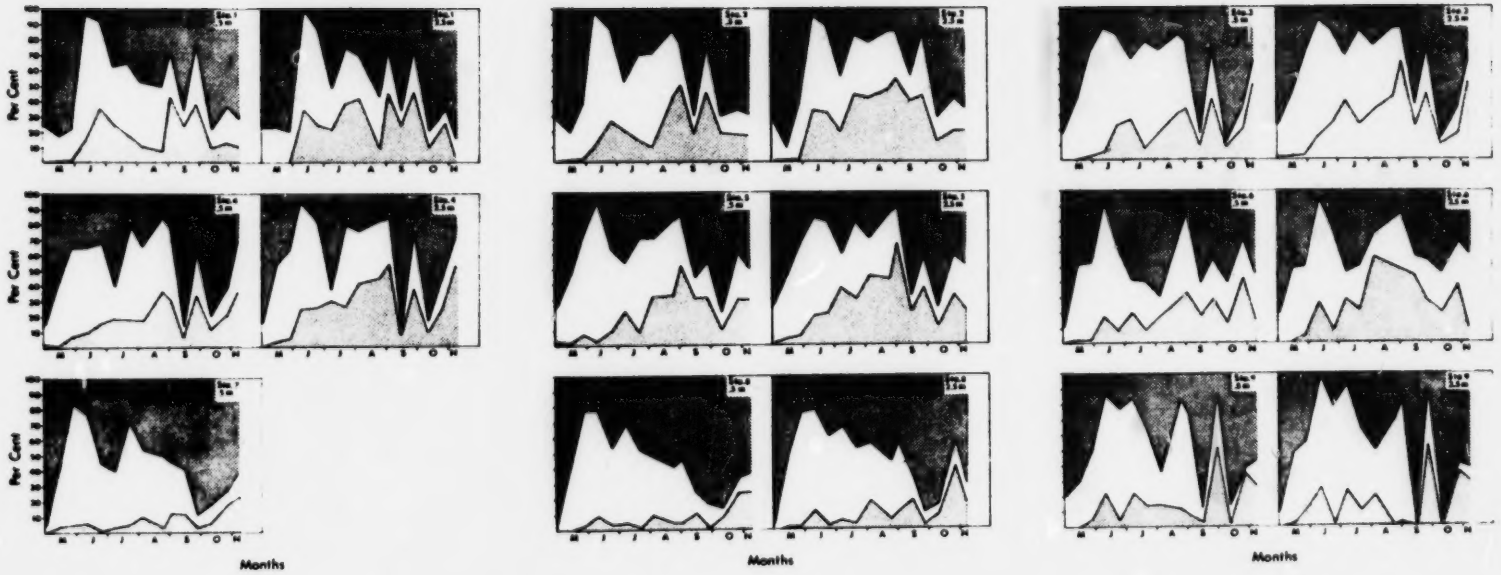

Figure 2. Mean seasonal variation in the compositional density of the major zooplankton groups. Top stipling-rotifers; middle clear area-copepods; bottom stipling-cladocerans. (From Malepa, 1972).

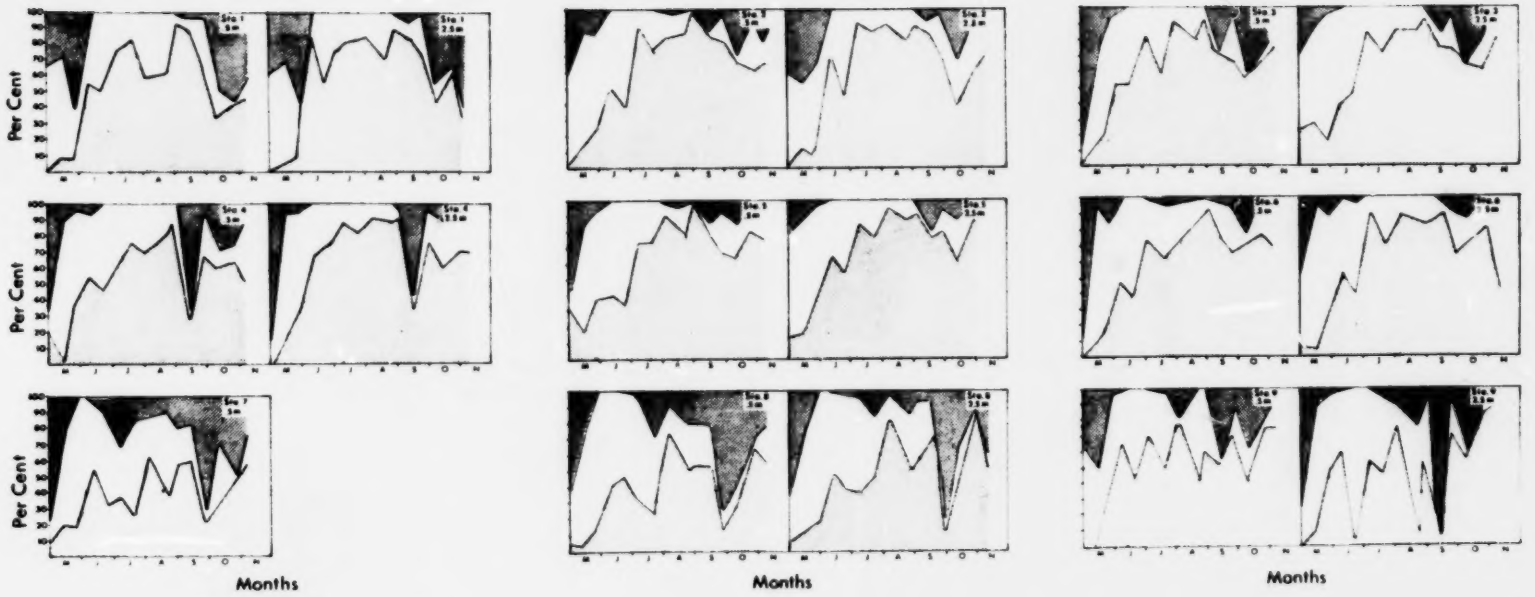

Figure 3. Mean seasonal variation in the composition of biomass of the major zooplankton groups. Top stipline-rotifers; middle clear area-copepods; bottom stipline-cladocerans. (From Nalepa, 1972).

in the analysis. Any selection that can be identified under these variable conditions should point to the generality of any selection process shown and increase our confidence in its validity.

In view of these considerations my work is not like the classical electivity studies which dictate simultaneous sampling of predator and prey at the same location (Ivlev, 1960). That type of study has been criticized by O'Brien and Vinyard (1974). It is rarely known whether or not the predator and the prey are collected from the same place where feeding interactions occurred because fish are mobile (Sigler, 1949; Hasler *et al.*, 1969), plankton are carried by currents, and there are often delays of hours or more in the digestion of fish stomach contents (Pearse and Achtenberg, 1920; Seaburg and Moyle, 1964; Noble, 1973).

Sampling

The sampling sites were located in the most disparate environments found in the study area: from the mouth of the Raisin River, the discharge canal and the lake. These were the same sites sampled by Nalepa (1972). This scheme ensured that any spatial heterogeneity in prey distributions which could confound our results would be identified. Fish and zooplankton samples were collected from the study area usually within 24 hours of one another at five sampling sites (see Appendix, Table A1). At the three lake stations fish were collected within one km of the zooplankton sampling station. Benthic samples were obtained from the same locations where zooplankton were collected and within a week of fish sampling. Fish, zooplankton, and benthos were sampled at the same site in the river and discharge canal. It is

very difficult to sample the water-sediment interface effectively and dense concentrations of various planktors may have occurred there and biased the results. However, Nalepa (1972) indicated that day and night samples were not consistently greater or different in concentrations of important zooplankton species. Therefore, daily migration which could cause high concentrations near the bottom at certain times of the day do not seem to have much impact in the study area.

Triplicate zooplankton samples were taken with an 8 liter VanDorn water bottle from 2.5 m (about mid-depth), filtered from 4 liters with a #25 Wisconsin plankton bucket and washed into a vial with 5% formalin for preservation. Animals were identified to the lowest possible taxa and counted using a Sedgwick-Rafter cell and a binocular scope at 100x. Lengths and widths of each individual were measured and an estimated third dimension was calculated as a proportion of the length from ratios derived from actual measurements. The volumes of the animals were then calculated by assuming the shape of each species was represented by an appropriate simple geometric form or combination of such forms (see Appendix, Table A2). Benthic animals were treated in a similar manner.

Four fish species were included in this study because of their importance based on abundance and economic value. The species examined were: goldfish, *Carassius auratus* (Linneaus); white bass, *Morone chrysops* (Rafinesque); freshwater drum, *Aplodinotus grunniens* (Rafinesque); and, yellow perch, *Perca flavescens* (Mitchill). The fish were collected with a 5 m otter trawl in duplicate five minute tows over an area of approximately 0.5 h. Fish were preserved in formalin

and aged from scales and length-frequency data. Later, the gut contents including the entire alimentary tract were analyzed by removing the stomach contents from the gut. Food organisms were suspended for subsampling and examination in a Sedgwick-Rafter cell under 100x. The volumes of these animals were calculated similarly to the volumes of those captured in water samples. When only parts of prey were found in the stomach, the volume of the whole animal was calculated from appropriate proportions. At least 20 organisms were counted from each stomach used in the analysis and each was identified to the most specific taxon possible.

Food sizes in different age classes of each fish species were contrasted among and within species using ANOVA tests after the data were corrected to homogeneous variances by log transformation (Sokal and Rohlf, 1969). Tukey's multiple range comparisons were used to sort mean values at $\alpha = 0.05$ when differences were determined to be significant ($\alpha = 0.05$) in the ANOVA (Glass and Stanley, 1970).

All comparisons were made without reference to specific dates or stations sampled. This is acceptable because no seasonal trends in sizes of prey consumed were suggested by plotting size of food against the time of the year and no identifiable differences in mean size of organisms in the stomach contents existed among stations (see Appendix, Table A3).

Electivity indices (Ivlev, 1960) although mostly qualitative, were calculated to identify possible selection of specific zooplankton taxa over the study period. A multivariate T-test (Gill and Hafs, 1971; Kramer, 1972) was employed to test the hypothesis that fish select certain zooplankter foods from their environment rather than consume

them in proportion to their abundance. The regression of prey size distribution and size of food organism in stomachs was also analyzed to assess the effect of size on the selection of prey.

RESULTS

Kinds of Food Consumed

The stomachs of the four fish species included in this study contained a wide variety of organisms, but size of prey appeared to be a primary cue used to select foods (Table 1; Figure 4). Some very rare but large organisms were found in the stomachs but not in the aquatic environment. Of the large organisms found in the water and benthic zones, only oligochaetes were absent in the stomachs (Table 1). Most frequently the favored foods included midge (Chironomidae) larvae or the large cladoceran, *Leptodora kindtii* (see Appendix, Tables A4-A7). The size of these two food types far exceeds that of other foods found in these fish (Table 1). Goldfish stand out as the exceptional species which contained foods of intermediate rather than larger sizes, especially the cyclopoid copepods.

Prey Selection

Stomach contents and species lists for the aquatic environment alone can do little more than suggest the potential importance of food selection from the potentially available prey species. Electivity indices for zooplankters demonstrate the regularity of selection of larger zooplankters and results of the multivariate T-test indicate the statistically significant ($\alpha = 0.05$) selection or rejection of prey species (Table 2; Appendix A15-A19). All four species showed

Table 1. The mean sizes of available food organisms and those consumed by fish.

Food Organisms Found in the Water	Mean Size $\mu^3 \times 10^6$	Reference Size for Figure 3	Range $\mu^3 \times 10^6$	Presence (X) in Fish Stomach			
				Yellow Perch	Fresh-Water Drum	White Bass	Goldfish
Chironomus sp.	59763	1	6620-204,000	X	X	X	X
Procladius sp.	58980	2	5970-204,000	X	X	X	X
Leptadora kindtii	1643	3	366-3522	X	X	X	X
Daphnia galeata mendotae	34.5	4	2-208	X	X	X	X
Daphnia retrocurva							
Diaphanosoma leuchtenbergiana	20.0	-	5-38		X		X
Ceriodaphnia sp.	20.0	-	ONE ONLY				
Calanoida							
Diaptomus ashlandi							
Diaptomus minutus							
Diaptomus sicilis	15.2	5	8.1-89.9	X	X	X	X
Diaptomus siciloides							
Diaptomus oregonensis							
Eurytemora affinis							
Cyclopoda							
Cyclops vernalis							
Cyclops bicuspidatus	9.2	6	8.1-89.9	X	X	X	X
Tropocyclops prasinus							
Harpacticoida†							
Canthocampus robertcokeri†	34						X
Bosmina sp.	8.4	7	1.6-26.6	X	X	X	X
Chydorus sp.	7.54	8	1.4-22.0	X	X	X	X

Table 1 (Cont'd)

Food Organisms Found in the Water	Mean Size $\mu^3 \times 10^6$	Reference Size for Figure 3	Range $\mu^3 \times 10^6$	Presence (X) in Fish Stomach: Yellow Perch	Fresh-Water Drum	White Bass	Goldfish
Copepod nauplii	.6	-	.19-1.5				
Rotifera	.85	9	.08-11.5	X		X	X
Oligocheta	8702		830-35,500				
FOOD FOUND IN STOMACHS, BUT NOT IN WATER							
Alona sp.	18.9		4-31		X	X	X
Ilyocryptus sp.	11.0		4-20	X	X		X
Daphnia ephippia	48.9		20-79		X	X	X
Isopoda*	145,450			X			
Amphipoda*	162,580			X			
Hydropsychidae*	72,400			X			
Hydrophyllidae*	90,360			X			
Acarnia (water mite)*	87			X			
Fish Remains*						X	

†Probably not representative, very few specimens.

*Each organism occurred once in only 1 or 2 stomachs.

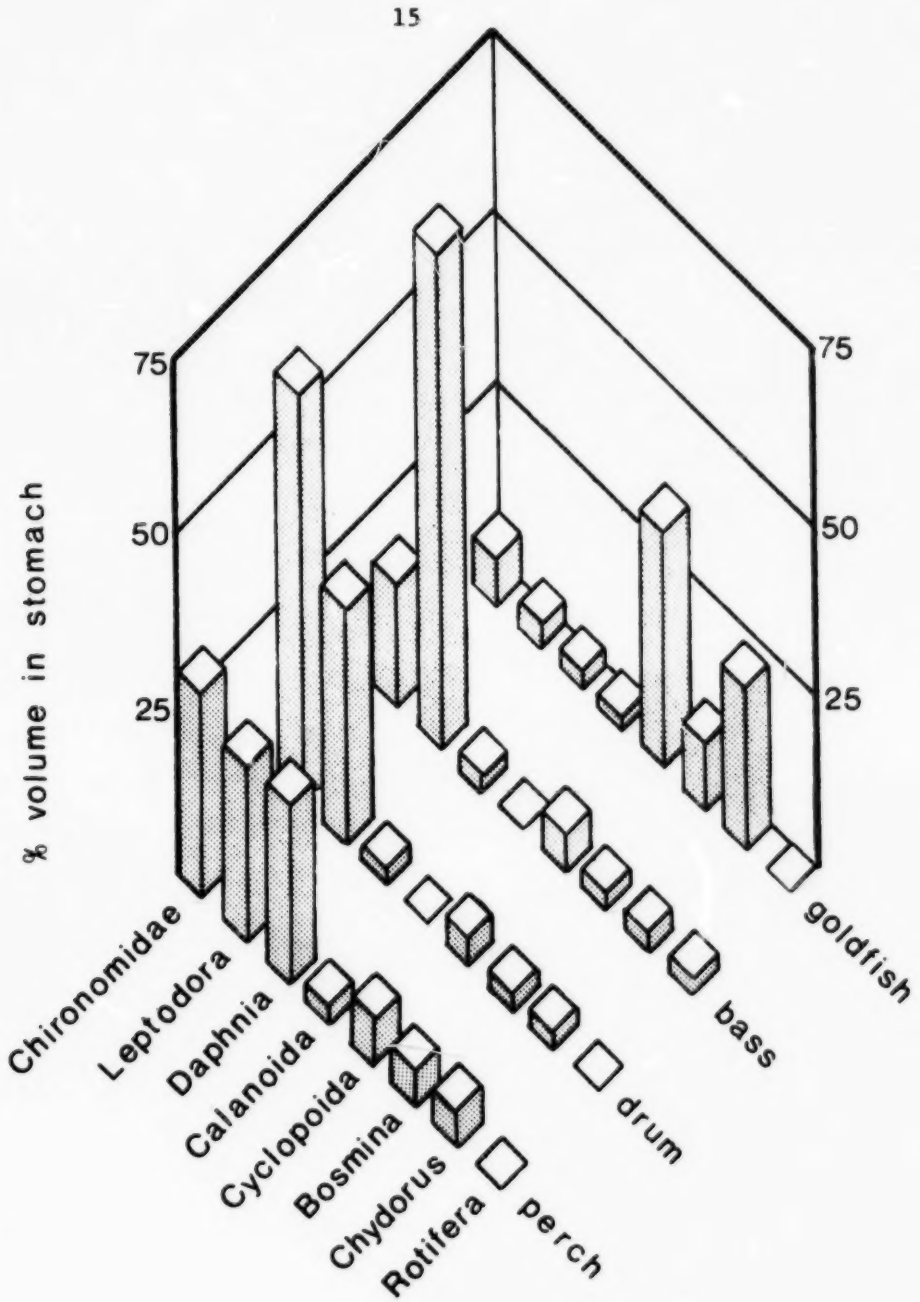

Figure 4. Percent of various foods found in stomach of four species of fish.

Table 7. Food electivity indices of yellow perch, freshwater drum, white bass and goldfish.[1]

Food Species Consumed	Fish Species Studied			
	Yellow Perch	Freshwater Drum	White Bass	Goldfish
Leptodora	+0.71*	+0.62*	+0.64*	+0.38
Daphnia	-0.13	-0.63*	-0.82*	-0.89*
Calanoida	+0.12	-0.98*	-0.98*	-0.79*
Cyclopoida	+0.26	+0.06	-0.32*	+0.61*
Bosmina	-0.42*	-0.96*	-0.73*	-0.32*
Chydorus	-0.07	-0.89*	-0.66*	-0.07
Rotifera	-0.99*	-1.0 *	-0.98*	-0.99*

[1]All fish greater than 50 mm.

*Denotes significantly different from zero at $\alpha = 0.05$ determined by a multivariate T, Student's t and approximate t tests.

some selection based on size but size-independent factors probably are responsible for selection among similarly sized smaller organisms. Among the four species, goldfish was the exception which selected for cyclopoids rather than *L. kindtii* as its main food item.

Although prey size seems to be an important selection factor for at least 3 of the 4 species examined, not one of the coefficients for regression analyses of the zooplankter stomach contents of the size composition of available zooplankton foods was significant (Figure 5). Addition of benthic forms reduced the regression coefficient for all species except drum, which increased somewhat but remained non-significant. Compared regression coefficients for data with and without benthic foods were significantly different for white bass, and drum ($p \simeq 0.04$ that r values are the same), while coefficients were similar in perch and goldfish ($p > 0.12$ and 0.35 respectively that r values are the same). Although none of the relationships shown in Figure 5 were statistically significantly different from zero at $\alpha = 0.05$, both bass ($r = 0.666$) and drum ($r = 0.705$) would be different from 0 at $\alpha = 0.10$ while perch ($r = 0.444$) and goldfish ($r = 0.279$) would be different only at much higher probabilities. Data shown in Figure 5 were logarithmicaly transformed because the actual values essentially resulted in a regression line between two widely divergent clumped groups of large and small organisms. The size selection of the benthic animals from bottom sediments may be obscured because position of the food in the sediment profile has such a marked impact on availability to the predator.

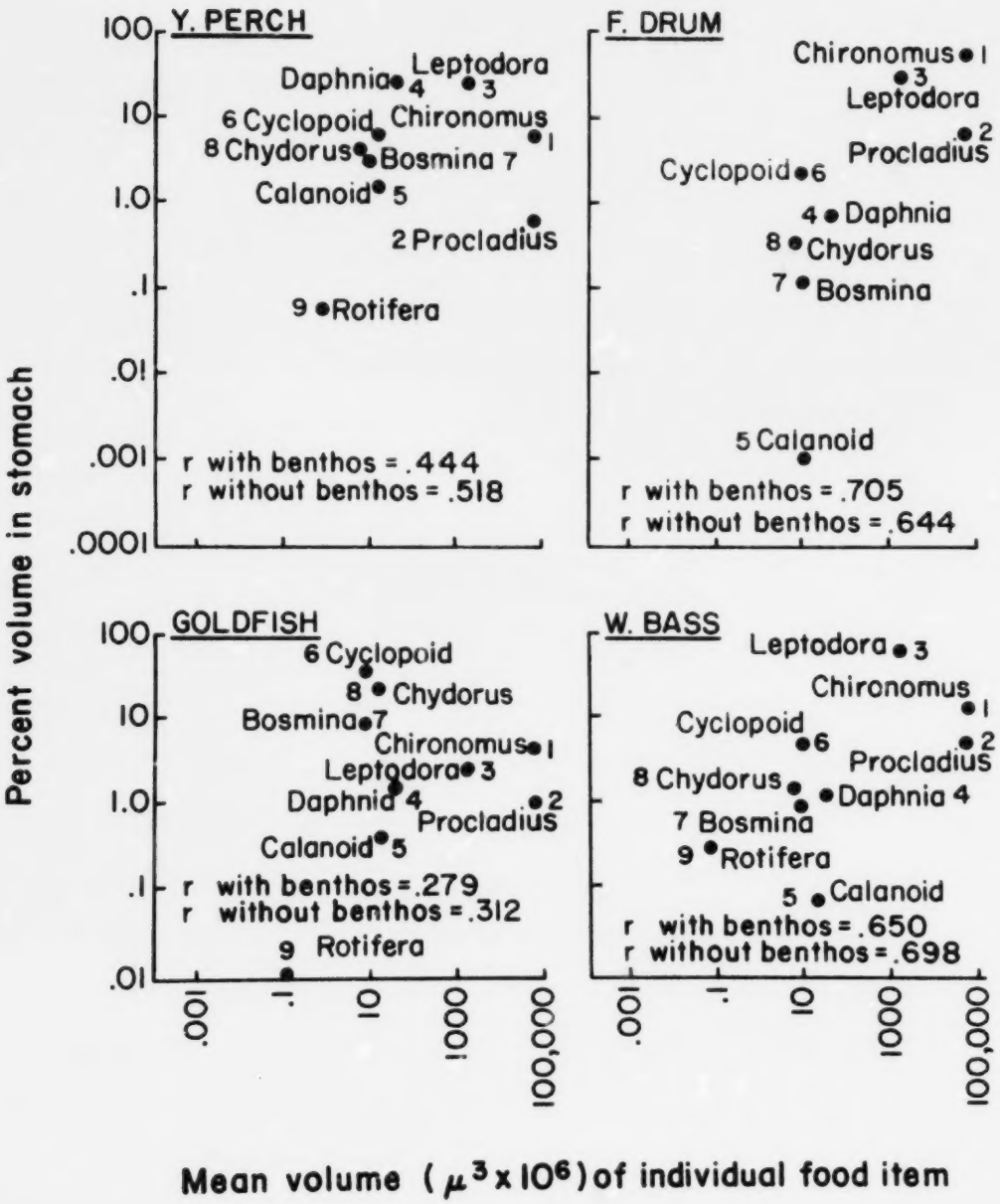

Figure 5. M The relationship between the mean percent volume of a species found in the stomach and the mean volume of individual food species found in the water.

Numbers denote size relationships among species. (Table I)

Only among drum is the largest available food organism, *Chironomus* sp., the most commonly consumed, with *L. kindtii* a close second. In white bass and yellow perch, *L. kindtii* was most commonly consumed rather than the larger benthic animals which were perhaps capable of avoiding capture by less effective benthic feeders through burrowing out of sight in the sediments. The benthic midge *Procladius* sp., in no case was preferred to *Chironomus* sp. or *L. kindtii* even though its size was very similar to *Chironomus* sp. *Procladius* sp. is translucent and *Chironomus* sp. is red and more likely to be visible in the sediments. In goldfish the preferred species were intermediate in size. The smallest foods, rotifers, contributed least to food volume in yellow perch and goldfish. These organisms are so small that it is possible they were consumed accidently in association with other food. In that case, *Bosmina longirostris* and *Chydorus sphaericus* would have been the smallest of the "selected" foods. Calanoid copepods may have avoided selection by all fish (Lindstrom, 1955) as they avoided tow nets (Fleminger, 1965) while cyclopoid copepods were more susceptible to predation. *Daphnia* sp., relatively large cladocerans, were negatively selected, possibly because of their transparency.

Age and Species of Fish and Food Selected

If fish food selection is determined substantially by size, the potential exists in the study area for both intraspecific and interspecific competition because the sizes of food used by most of the fish species examined differed little after they reached a certain age (Figure 6). At present, zooplankton food does not appear to be in short supply in the very productive western basin. The mean size

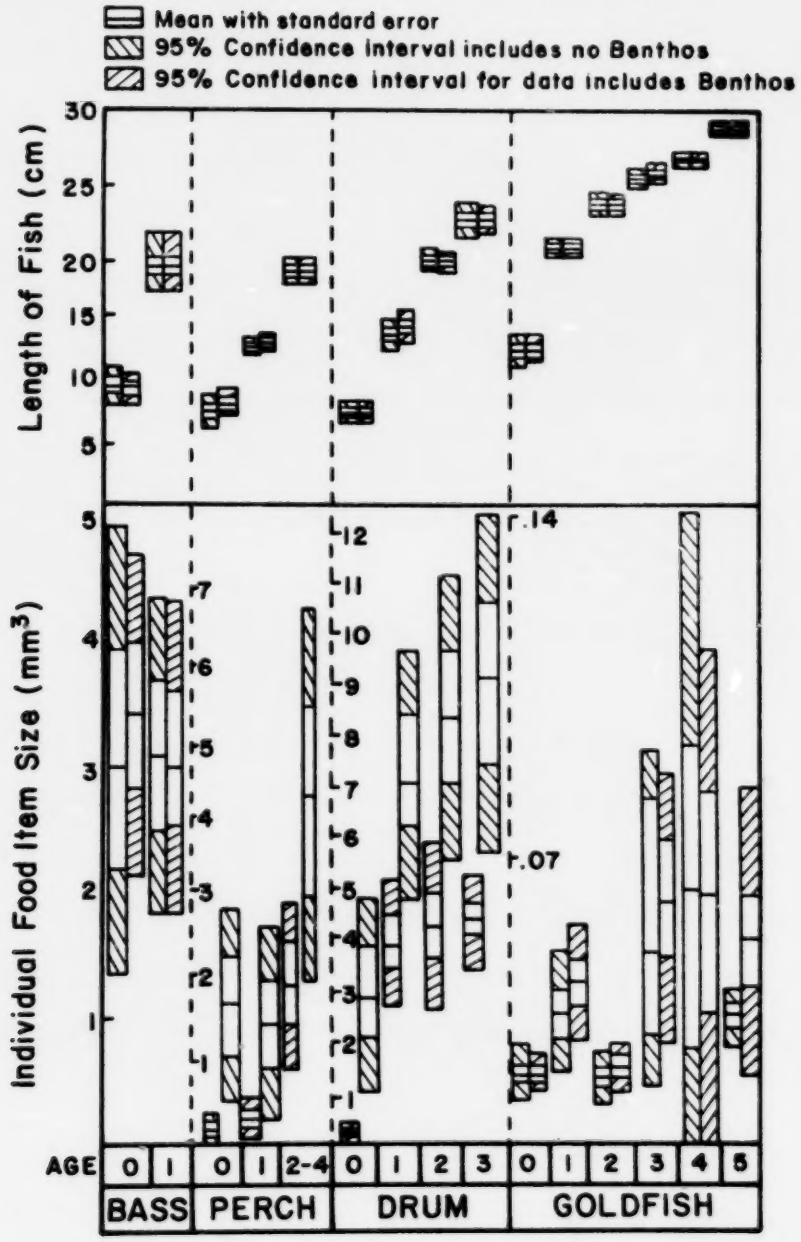
Mean with standard error
95% Confidence interval includes no Benthos
95% Confidence interval for data includes Benthos
Length of Fish (cm)
Individual Food Item Size (mm³)
AGE
0 1 0 1 2-4 0 1 2 3 0 1 2 3 4 5
BASS
PERCH
DRUM
GOLDFISH

Figure 6. The mean food size of organisms consumed by different fish age classes.

Note that each fish species is on a different scale and that these are different than those shown on Figure 7.

of all food consumed by an individual species differed ($\alpha = 0.05$) among age classes only in the young-of-the-year freshwater drum. Yellow perch also exhibited a trend in the relation between age and food size and when the more size-variable benthic organisms were deleted from the analysis, the young-of-the-year perch exhibited stomach contents with sizes that differed from ages 2 through 4. For the most part, the mean size of food in stomach contents varies little once the fish in all four of these species reach 6 to 10 cm (see Appendix Tables A8-A11).

Based on food size alone, there seems to be enough difference ($\alpha = 0.05$) in the stomach contents of young-of-the-year fish to preclude intensive interspecific competition at this size (Figure 7). But, as the fish grow larger, differences in food sizes among three of the four species are not apparent. This is at least partly caused by greater variation in the food sizes eaten by larger fish. Goldfish again stand apart as the least likely to compete with any of the other species examined as the mean size of prey in their stomach contents is significantly less than that of the other species (see Appendix Tables A12-A14).

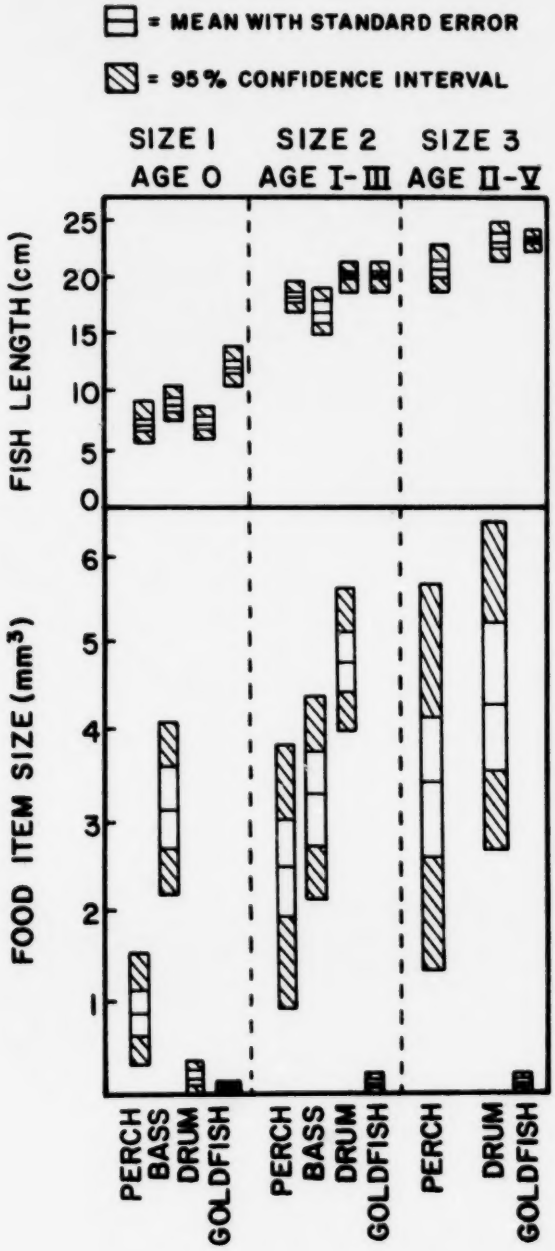

Figure 7. Comparison of mean food sizes consumed by different species within different size groups of fish. Fish of different species were selected for similar size without specific reference to age. Therefore age and size catagories only approximate each other.

DISCUSSION

The Impact of Prey Size on Trophic Dynamics

Size selection of prey by fish predators has been discussed at length by many workers (Carr and Hiltunen, 1965; Galbraith, 1967; Reif and Tappa, 1966; Hrbacek, 1958; Wells, 1970; Brooks and Dodson, 1965; Brooks, 1968; Hutchinson, 1971; and others). Size appears to play a role in the food selection process of fish in western Lake Erie, particularly in the zooplankter component. But, because so much of the size related choice depends on one or two prey species in Lake Erie (*Leptodora kindtii* and *Chironomus* sp.) there remains some doubt that prey size is the primary selective cue used by the predator. Size could be only spuriously related to some size independent vulnerability, such as speed of movement, opacity or contrast. The fact that large benthic organisms were actively selected by two of four fish species even though the zoobenthos are physically more likely to be obscured than zooplankton strengthens the belief that size is an important regulatory factor.

The smaller zooplankters appear to be selected on the basis of characters other than the relatively minor size differences that exist among them. Relative density of prey probably becomes more important, but certain prey groups seem to be vulnerable to predators for reasons other than size or density. Other workers have described phenomena which may influence the visual selection of organisms for food.

Zarret (1972) thought that large eye spots and dark digestive tracts in prey may trigger selection; and brightness, contrast (Hemmings, 1966) and color (Ginetz and Larke, 1972) may also be involved. Greze (1963) hypothesized that transparency as a form of protective coloration was important; the more opaque the organism, the greater is its susceptibility to predation. The actual sighting range of a predator probably depends on prey size, contrast, and illumination. In Lake Erie, the latter is markedly influenced by excessive turbidity. Brooks (1968) felt that movements would attract fishes to an organism and Hall *et al.* (1970) thought that in addition to body size, selection also involved the habitat, abundance, and the vulnerability, competition and activity of the prey species. Some species of zooplankton are capable of avoidance reactions; notably the calanoid copepods and *L. kindtii* (Szlauer, 1967; Szlauer, 1965; Lindstrom, 1955; Aron and Collard, 1969). It appears from these investigations, as well as others, that prey size selection operates most effectively when a wide choice of sizes is available. As the range of different prey sizes diminishes, other selection cues must be utilized.

Brooks and Dodson (1965), Galbraith (1967), Hrbacek *et al.* (1961), and others believed that fish selected the larger, competitively superior feeders which allowed a greater diversity and abundance of smaller species to develop. The hypothesis that a minimum size threshold exists for prey before perch, bass and drum actively seek those organisms is supported by LeBrasseur (1969), Brooks (1968) and others who found that organisms below a given size range were ignored or rejected when larger alternative organisms were present. According to Hall *et al.* (1970) fish consume a greater diversity of species when food is scarce although generally they eat the largest food possible.

Each of the four species of fish investigated in the study consumed unique combinations of prey species but virtually all species were consumed by each fish species. Therefore, it is possible that a loss of any one relatively important prey species could cause a shift in feeding intensity on the remaining prey organisms and in turn affect the relative growth and distribution of the fish species. Any new size related shift in prey abundance, such as might be caused by power plant operation would be less likely to directly influence fish like goldfish than species like white bass, drum and perch which depend heavily on large food organisms. A shift of this type may have already occurred following the depressed oxygen levels of the mid-1950's.

Historically, these three fish extensively used even larger benthic food items (Price, 1963) such as large burrowing mayflies (Hexagenia), caddisflies (Trichoptera), scuds (Amphipoda), sowbugs (Isopoda), and fingernail clams (Sphaeridae), but these populations have been decimated since the early 1950's when mortalities associated with extreme oxygen depletion was first recognized in the western basin of Lake Erie (Britt, 1955; Verduin, 1964). Extremely low oxygen levels have occurred repeatedly in the western basin since then and apparently contributed to the demise of intolerant species and the depression of food size diversity. Carr and Hiltunen (1965) reported that from 1930 to 1960 Hexagenia had dropped to 1% of its former abundance, while tubificids had increased ninefold and chironomid larvae had increased fourfold. Tubificids apparently are not available as food to most fish even though they are relatively large probably because they move quickly into the sediments. With Hexagenia and

other large benthic species decimated, the fish were forced to rely more on chironomid larvae and zooplankton. Although the total biomass of benthic organisms present may have remained the same or even increased over time in Lake Erie, the number of large species available for consumption has been drastically reduced. At the present time, zooplankton prey density does not appear to limit growth, but their small size, in relation to predator size, may have decreased fish feeding efficiency and depressed fish growth rates.

Power plant entrainment may cause more damage to larger plankton like *L. kindtii* than to smaller species of zooplankton because they could be more susceptible to mechanical damage in once-through cooling systems (McNaught, 1972). Normally, sustained growth rates require increasingly larger prey as the predator becomes larger. LeBrasseur (1969) and Kerr (1971) discuss the importance of efficient feeding based on the relative energy costs required to capture a few large organisms compared to many small ones. Growth efficiency probably decreases when these prey organisms become rare or small in relation to the predator size because the metabolic cost of excessive searching for food is appreciably higher, according to Pierce and Wissing (1974) than normal swimming activity alone. In Lake Erie a restricted few, relatively small prey species are consumed by all fish older than a few months, and although they appear to be fairly abundant, this may contribute to depressed growth rates in older fish. Any additional negative impact on larger food organisms could depress growth rates further in all age groups of size-selective feeders and favor growth in fish species that are less likely to select food by size. Because of these potential effects, power plant cooling operations could cause

indirect and subtle, but real changes in the fisheries resource. These speculations deserve attention in further refined studies of power plant effects on entrained organisms.

Conclusions

1. Large prey organisms (specifically *Leptodora kindtii* and *Chironomus* sp.) are selected for food by freshwater drum, white bass and perch. Goldfish select smaller prey species; particularly cyclopoid copepods.

2. Among freshwater drum, white bass and perch, fish older than age 1 eat similarly sized organisms and therefore may compete interspecifically. Young-of-the-year fish are less likely to compete because the food sizes consumed are more diverse. Goldfish eat different sized foods from the other fish species at all ages, so are unlikely to compete interspecifically.

3. All ages but young-of-the-year fish in each species eat food of about the same size and may compete intraspecifically.

4. Given a history of decreasing size diversity in fish food organisms in western Lake Erie, any further depression, such as might possibly result from an increase in the number of power plants and other operations, could cause subtle changes in fish species composition and growth rates which may favor fish species like goldfish and disfavor fish species like perch, drum and white bass. Additional data on power plant effects on the prey are needed to validate these speculations. Extensive quantitative data describing the extent of impact on prey populations and differential, size related mortality are needed to make management recommendations.

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Table A1. Sampling dates for zooplankton and fish.

Zooplankton Collection Dates	Fish Collection Dates
05/11/72	05/11/72
05/31/72	06/02/72
06/13/72	06/14/72
06/27/72	06/29/72
07/11/72	07/12/72
07/25/72	07/25/72
08/16/72	08/16/72
08/29/72	08/29/72
09/12/72	09/13/72
09/29/72	09/30/72
10/13/72	10/13/72
10/27/72	10/27/72
07/14/71	07/14/71
07/30/71	07/29/71
09/02/71	08/31/71
09/17/71	09/16/71
10/02/71	09/31/71
10/15/71	10/15/71
10/31/72	10/30/71
12/07/71	12/07/72

Table A2. Geometric forms used to determine volume of food organisms (Weast, 1968).

Daphnia sp. *Alona* sp. *Daphnia* ephippia *Diaphanosoma* sp.	$1/6\ \pi\ abc$	where a = length - measured excluding tail spine b = width - measured at widest point c = depth - (.29)a
Chydorus sp.	$4/3\ \pi\ r^3$	where r = 1/2 the length or width
Bosmina sp. *Ilyocryptus* sp.	$1/6\ \pi\ abc$	where a = length - measured at widest point b = width - measured at widest point c = depth - (.51)a
Cyclopoida Calanoida	$\dfrac{\pi r^2 a + \frac{\pi r^2 a}{3}}{2}$	where r = 1/2 width at widest point a = length excluding caudal setae
Harpacticoida Chironomid larvae	$\pi r^2 a$	where r = 1/2 width at widest point a = length excluding caudal setae
Leptodora kindtii	$\pi r^2 a$	where r = 1/2 width of the main body segment at widest point a = length of the tail x a factor based on the width of the tail at the very base, which was based on proportional measurement of the whole of the body parts

Table A3. Differences in mean size (mm^3) of food in stomach contents among stations.

Fish Species	Station Number	Means	Sum of Squares		d.f.	Mean Square	"f" ratio	Probability
Yellow Perch	1	.849	total	115.696	65	1775	f_{calc} = .097	>.75
	2	.765	trts	.354	2	.177	f = 0.05 (2,63) = 3.15	
	3	.670	error	115.292	63	1.830	table	
White Bass	1	2.179	total	95.220	27	3.527	f_{calc} = 1.317	
	2	2.358	trts	13.462	3	4.487	f = 0.05 (3,24) = 3.01	.50
	3	2.767	error	81.759	24	3.407	table	
	4	3.959						
Freshwater Drum	1	2.162	total	189.137	38	4.977	f_{calc} = .590	
	2	3.092	trts	6.009	2	3.005	f = 0.05 (2,36) = 3.32	.50
	3	2.838	error	183.129	36	5.087	table	
Goldfish	1	.018	total	.0025	37	.00007	f_{calc} = 3.39	
	3	.023	trts	.0002	1	.00021	f = 0.05 (1,36) = 4.08	.10
			error	.0023	36	.00006	table	

Table A4. Percent of Yellow Perch stomachs in which food species occured.

No. of Fish	43	24	10	13	7	4	
Food Species	Age 0	Age I	Age II	Age III	Age IV	Age V	All Ages
Amphipod	7	--	10	--	--	25	4.95
Chironomus	40	25	50	23	29	50	34.65
Procladius	9	8	10	--	--	25	7.92
Nematode	5	4	--	--	--	--	2.97
Coeleotanypus	2	--	--	--	--	--	.99
Hydropsychidae	--	4	--	--	--	--	.99
Leptodora	35	29	30	46	71	25	36.63
Daphnia	56	62	40	54	57	--	53.46
Calanoida	28	4	20	--	--	--	14.85
Ilyocryptus	--	--	--	8	--	--	.99
Cyclopoida	60	21	30	8	--	75	37.62
Bosmina	22	17	20	31	--	50	33.66
Chydorus	12	4	20	15	43	50	14.85
Rotifera	5	4	--	8	--	25	4.95

Table A5. Percent of white bass in which food occurred.

No. of Fish	25	16	
Food Species	Age 0	Age I	All Ages
Chironomus	40	--	24.39
Procladius	32	--	19.51
Nematoda	16	13	14.6
Leptodora	100	75	90.24
Daphnia ephippia	12	--	7.32
Daphnia	56	25	43.9
Ceriodaphnia	8	--	4.88
Alona	4	--	2.44
Calanoida	12	25	9.76
Ilyocryptus	4	--	2.44
Cyclopoida	60	56	56.1
Bosmina	40	38	39.02
Chydorus	24	12	19.51
Rotifera	--	6	2.44
Fish Bones	8	31	17.07
Fish Scales	44	50	46.34
Tape Worm	16	44	26.83

Table A6. **Percent of freshwater drum in which food occurred.**

No. of Fish	24	24	18	12	5	2	2	
Food Species	Age 0	Age I	Age II	Age III	Age IV	Age V	Age VI	All Ages
Chironomus	75	58	72	58	80	100	--	66.67
Procladius	29	25	44	42	40	50	--	33.33
Nemadota	4	8	--	8	--	--	--	4.60
Leptodora	25	62	56	100	60	50	100	56.32
Daphnia ephippia	--	8	6	--	--	--	--	3.45
Daphnia	37	33	28	33	--	--	50	31.03
Diaphanosoma	4	--	--	--	--	--	--	1.15
Alona	8	4	--	--	--	--	--	3.45
Calanoida	8	4	--	--	--	--	--	3.45
Ilyocryptus	4	--	--	--	20	50	50	4.60
Cyclopoida	71	25	17	8	--	50	--	32.18
Bosmina	29	33	22	33	20	--	--	27.59
Chydorus	4	4	--	25	--	--	--	5.75
Fish Scales	33	25	28	50	80	--	--	33.33
Fish Bones	--	--	6	--	40	--	--	3.45

Table A7. Percent of goldfish in which food occurred.

No. of Fish	10	10	10	11	11	10	2	
Food Species	Age 0	Age I	Age II	Age III	Age IV	Age V	Age VI	All ages
Chironomus	--	10	10	45	9	9	--	14.06
Procladius	--	--	--	18	9	--	--	4.69
Leptodora	--	--	--	9	9	9	--	4.69
Daphnia ephippia	90	50	40	18	64	45	100	62.50
Daphnia	--	40	20	--	--	18	--	15.63
Harpacticoida	20	30	20	27	27	27	--	25.00
Diaphanosoma	--	--	--	27	27	--	--	10.94
Alona	70	80	80	73	82	73	100	81.25
Calanoida	--	--	30	--	--	9	--	6.25
Ilyocryptus	30	--	10	27	36	18	--	20.31
Cyclopoida	90	100	90	100	91	100	100	96.88
Bosmina	100	100	90	91	91	100	100	96.88
Chydorus	100	80	90	91	73	100	100	90.63
Rotifera	10	10	10	--	--	9	--	6.25
Fish Scales	--	--	--	9	--	--	--	1.56

Table A8. Percent volume of all food organisms eaten by age class (yellow perch).

Food Species	Age Class	0	I	II	III	IV
	No. of Fish	35	20	7	8	7
	Length Range	4.5-10.5 cm	11-14.5 cm	15-16.5 cm	17-19.5 cm	20-21 cm
		% Volume	% Volume	% Volume	% Volume	% Volume
Chironomus		25.20	23.58	68.42	12.48	18.25
Procladius		3.30	1.37	.31	----	2.42
Leptodora		28.02	18.88	5.45	45.84	64.98
Daphnia		26.60	46.20	9.63	16.67	1.50
Calanoida		1.45	0.78	8.75	----	----
Cyclopoida		13.75	2.71	6.91	.56	----
Bosmina		1.03	4.91	----	14.29	----
Chydorus		.65	1.57	.53	8.87	12.93
Rotifera		----	----	----	.71	----

Table A9. Percent volume of all food organisms eaten by age class (white bass).

	Age Class	0	I
	No. of Fish	22	15
	Length Range	6.5-12.5 cm	13-23.5 cm
Food Species		% Volume	% Volume
Chironomus		21.54	----
Procladius		10.34	----
Leptodora		65.83	78.77
Daphnia ephippia		.02	----
Daphnia		1.41	.87
Ceriodaphnia		.01	----
Alona		----	----
Calanoida		.14	.01
Ilyocryptus		----	----
Cyclopoida		.66	12.52
Bosmina		.03	2.63
Chydorus		.02	4.31
Rotifera		----	.89

Table A10. Percent volume of all food organisms eaten by age class (freshwater drum).

Food Species	Age Class	0	I	II	III	IV-V
	No. of Fish	20	22	18	13	5
	Length Range	4.5-10.5 cm	11-17.5 cm	18-20.5 cm	21-24 cm	24.5-26 cm
		% Volume	% Volume	% Volume	% Volume	% Volume
Chironomus		76.61	50.87	50.46	39.95	52.17
Procladius		5.51	.92	13.22	3.64	13.17
Leptodora		9.49	42.37	35.88	56.31	34.54
Daphnia ephippia		----	1.08	----	----	----
Daphnia		.94	1.26	.40	.02	.01
Diaphanosoma		.04	----	----	----	----
Alona		----	.09	----	----	----
Cyclopoida		7.32	1.61	----	----	.10
Bosmina		.07	.41	----	----	----
Chydorus		----	1.38	----	----	----

Table All. Percent volume of all food organisms eaten by age class (goldfish).

Food Species	Age Class	0	I	II	III	IV	V
	No. of Fish	7	9	9	12	10	12
	Length Range	10.5-18.5 cm	19-22 cm	22.5-24.9 cm	25-26.8 cm	27-28 cm	28.5-31 cm
		% Volume	% Volume	% Volume	% Volume	% Volume	% Volume
Chironomus		----	9.18	.78	12.05	6.90	4.02
Procladius		----	----	----	2.88	3.56	----
Leptodora		----	----	----	6.56	8.97	7.42
Daphnia ephippia		9.94	14.44	7.74	27.30	19.73	10.05
Daphnia		.67	4.18	2.85	----	----	2.29
Harpacticoida		----	.38	.17	.97	.86	.93
Diaphanosoma		----	----	----	1.60	1.90	.82
Alona		6.06	4.08	5.45	3.47	4.70	1.93
Calanoida		----	----	2.45	----	----	.47
Illyocryptus		.29	----	.06	.42	1.08	.69
Cyclopoida		22.98	42.41	27.45	25.33	41.26	36.18
Bosmina		4.82	6.44	19.97	10.33	4.05	10.29
Chydorus		55.25	18.84	33.07	9.10	6.98	24.90
Rotifera		----	.05	----	----	----	----

Table A12. Percent volume of foods eaten by smallest size fishes (size group 1 in Figure 7).

Food Species	Fish Species	Yellow Perch	White Bass	Freshwater Drum	Goldfish
	Length Range	4.5-10.5 cm	6-13 cm	4.5-9.5 cm	11-14.5 cm
	Months Collected	May-Sept	Aug-Oct	Sept-Oct	Oct-Nov
		% Volume	% Volume	% Volume	% Volume
Leptodora		54.17	97.94	14.43	----
Daphnia ephippia		----	.01	----	14.87
Daphnia		25.70	1.72	22.45	.47
Harpacticoida		----	----	----	.57
Diaphanosoma		----	----	----	.20
Alona		----	----	.43	6.52
Calanoida		2.31	.29	.30	----
Ilyocryptus		----	----	1.55	.16
Cyclopoida		13.80	.02	61.92	20.6
Bosmina		1.96	.02	.86	5.20
Chydorus		2.11	.001	.05	51.45
Rotifera		.002	----	----	.01

Table A13. Percent volume of foods eaten by medium-size fishes (size group 2 in Figure 7).

Food Species	Fish Species	Yellow Perch	White Bass	Freshwater Drum	Goldfish
	Length Range	17-20 cm	14.5-21.5 cm	18-22 cm	19-20.5 cm
	Months Collected	July-Oct	July-Oct	June-Aug	Aug-Oct
		% Volume	% Volume	% Volume	% Volume
Leptodora		73.96	66.02	99.24	----
Daphnia ephippia		----	----	----	16.70
Daphnia		3.79	.57	.77	4.18
Harpacticoida		----	----	----	.38
Alona		----	----	----	3.98
Ilyocryptus		.52	----	----	----
Cyclopoida		.49	20.43	.001	48.51
Bosmina		12.68	4.31	----	6.58
Chydorus		7.92	7.18	----	19.61
Rotifera		.63	1.49	----	.05

Table A14. Percent volume of foods eaten by largest size fishes (size group 3 in Figure 7).

Food Species	Fish Species	Yellow Perch	Freshwater Drum	Goldfish
	Length Range	20-24 cm	22-25 cm	22.5-24 cm
	Months Collected	July-Oct	Aug-Oct	Sept-Oct
		% Volume	% Volume	% Volume
Leptodora		82.99	99.86	----
Daphnia ephippia		----	----	13.10
Daphnia		.21	.13	2.70
Harpacticoida		----	----	.56
Alona		----	----	5.47
Calanoida		----	----	.30
Cyclopoida		.48	12.86	26.28
Bosmina		1.29	----	6.84
Chydorus		15.02	----	44.72
Rotifera		.01	----	----

Table A15. Mean annual electivity index for four species of fish.

Food Species	Goldfish	Sheepshead	White Bass	Yellow Perch
Leptodora	-.38	+.62	+.64	+.71
*Daphnia**	-.89	-.63	-.82	-.13
Harpacticoida	+1.0	----	----	-1.0
Calanoida	-.79	-.98	-.98	+.12
Cyclopoida	+.61	+.06	-.32	+.26
*Bosmina**	-.32	-.96	-.73	-.42
*Chydorus**	-.07	-.89	-.66	-.07
Rotifera	-.99	-1.0	-.98	-.99
Not found in water *Daphnia* ephippia	+1.0	+1.0	+1.0	+1.0
Not found in fish Nauplii	-1.0	-1.0	-1.0	-1.0
Rare *Ilyocryptus*	+1.0	----	----	+1.0
Rare *Diaphanosoma*	-.37	-1.0	-1.0	-1.0
Rare *Ceriodaphnia*	----	----	+1.0	----
Not ident. in water at all *Alona*	+1.0	+1.0	+1.0	----

*Found in both stomachs and water.

YELLOW PERCH

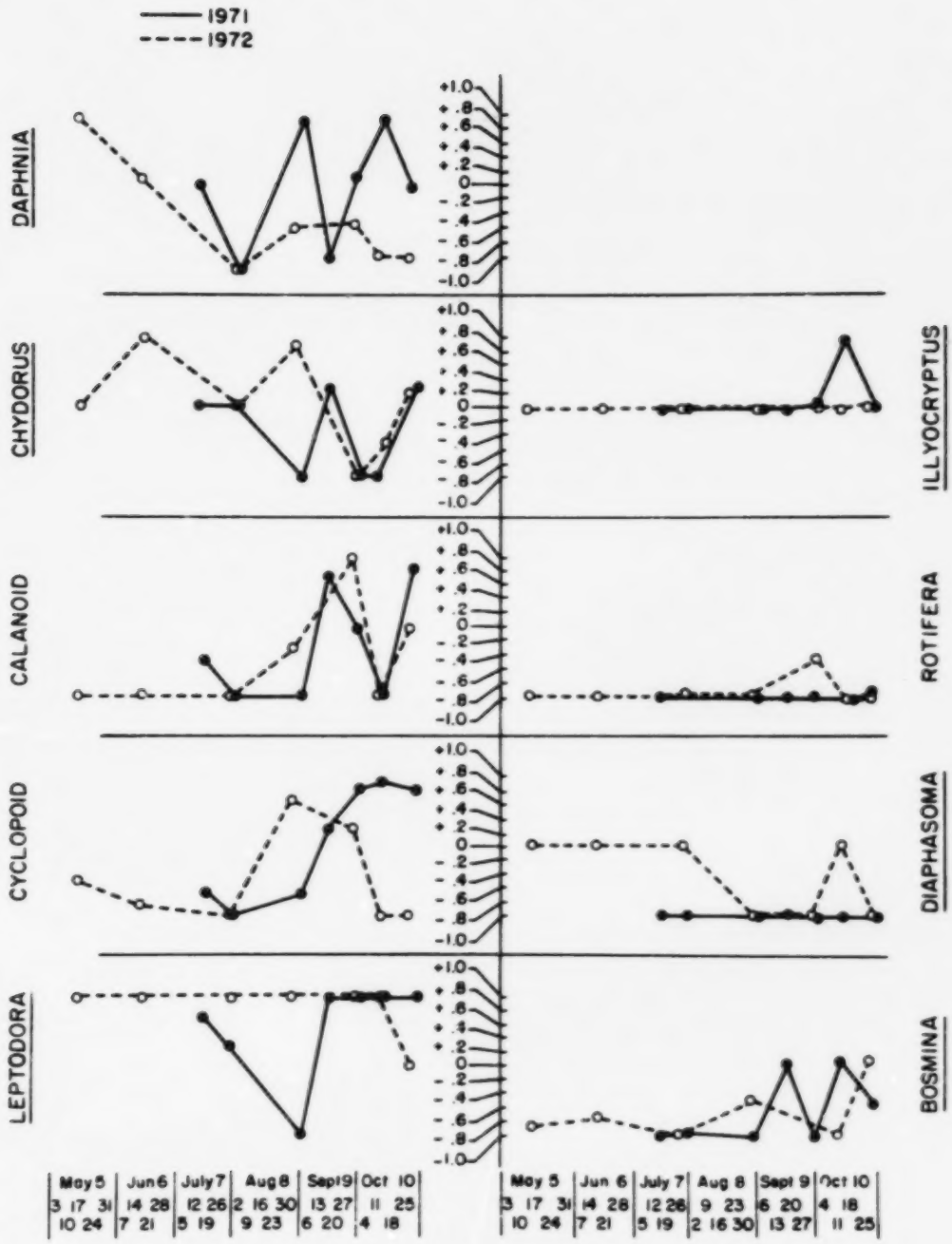

Figure A. 16. Electivity index (Ivlev, 1960) for yellow perch.

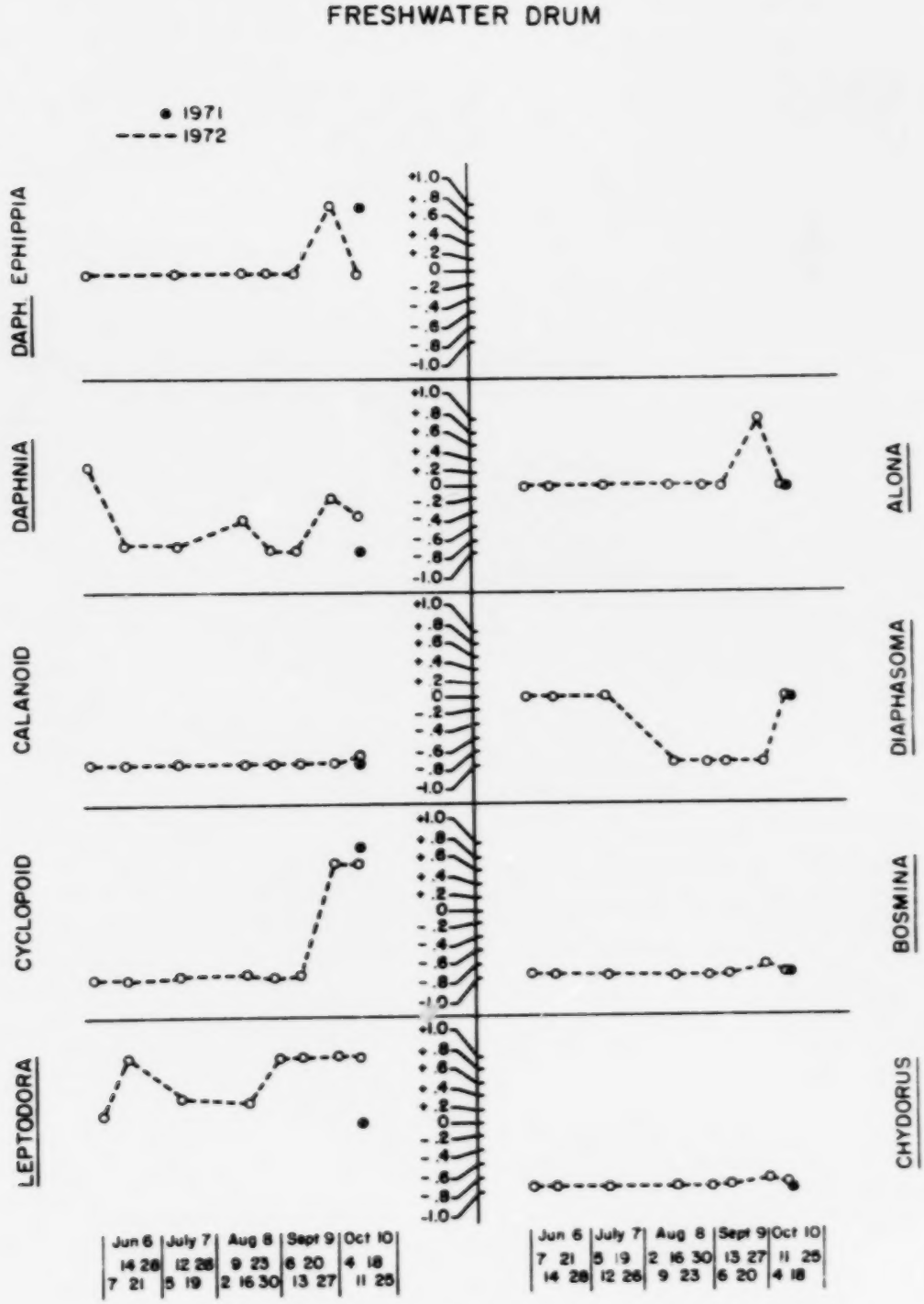

Figure A. 18. Electivity index (Ivlev, 1960) for Freshwater drum.

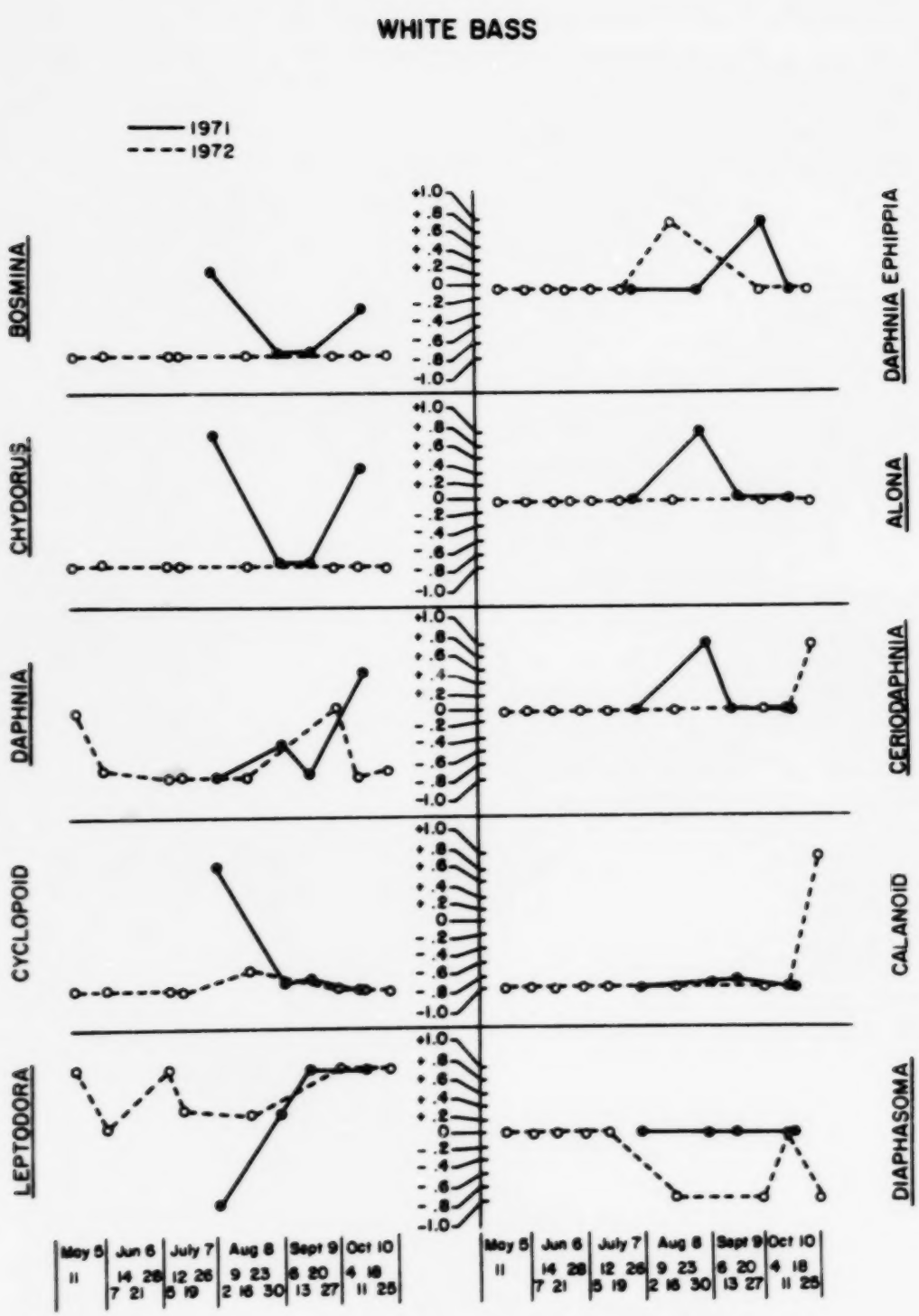

Figure A. 17. Electivity index (Ivlev, 1960) for white bass.

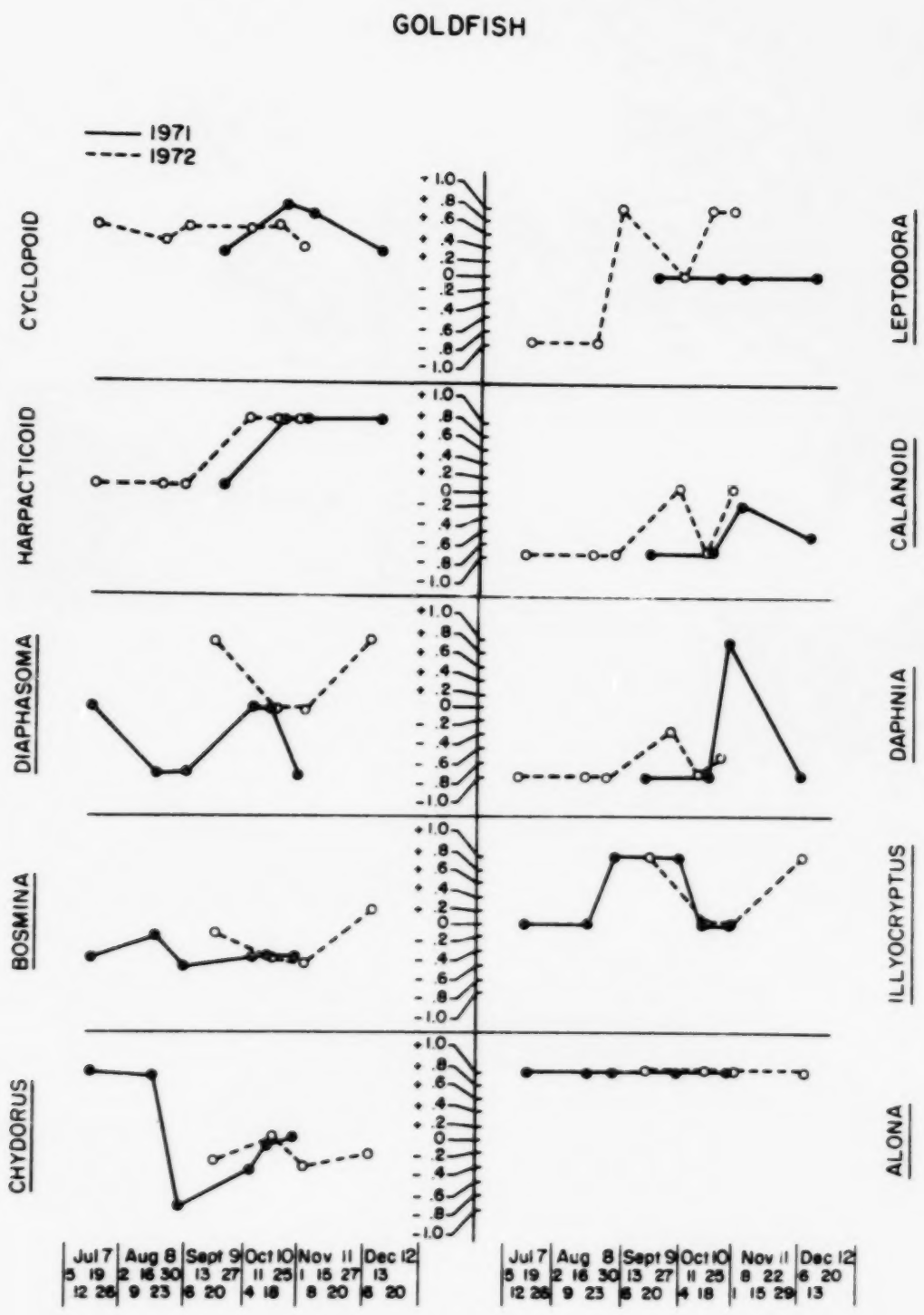
GOLDFISH
1971
1972
CYCLOPOID
HARPACTICOID
DIAPHASOMA
BOSMINA
CHYDORUS
LEPTODORA
CALANOID
DAPHNIA
ILLYOCRYPTUS
ALONA
+1.0
.8
.6
.4
.2
0
.2
.4
.6
.8
-1.0
Jul 7 | Aug 8 | Sept 9 | Oct 10 | Nov 11 | Dec 12
5 19 | 2 16 30 | 13 27 | 11 25 | 1 15 27 | 13
12 26 | 9 23 | 6 20 | 4 18 | 8 20 | 6 20
Jul 7 | Aug 8 | Sept 9 | Oct 10 | Nov 11 | Dec 12
5 19 | 2 16 30 | 13 27 | 11 25 | 8 22 | 6 20
12 26 | 9 23 | 6 20 | 4 18 | 1 15 29 | 13

Figure A. 19. Electivity index (Ivlev, 1960) for goldfish.